DIGITAL COMPUTATIONAL SYSTEMS AS AESTHETIC ARTIFACTS: PRACTICES, SYSTEMS, PROCESSES AND PERSPECTIVES

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This paper addresses the study of digital computational systems as aesthetic artifacts seeking to provide instruments for their analysis and critical understanding. Implied in this view, is the need to combine complementary perspectives considering both their specificity as digital computational (software-driven) systems and their different aesthetic intents and experiences. This approach also entails articulating the viewpoint of their creation or poetics with the viewpoint of their experience or aesthetics. To this end, this paper discusses concepts and frameworks that not only argue on the distinctive processual nature of these systems, but also stress the interdependency of views on their principles, mechanics and experience.

1. INTRODUCTION

This paper was motivated by a previous study of aesthetic artifacts that explore the possibilities of software as a creative medium and propose audiovisual interactive experiences. However the question that immediately emerges while confronting perspectives on the subject is that before addressing their audiovisual and interactivity specificity, a deeper understanding of digital computational systems as aesthetic artifacts is needed (Ribas 2012). Therefore, rather than focusing on their surface audiovisual modes of expression, this study is oriented towards understanding the dynamics of these systems. And rather than focusing on the specifics of audience interaction, it frames interaction as one of the dimensions of the variable dynamic behavior of these systems.

We begin by discussing complementary perspectives on the principles that motivate and drive the creation of these systems (framing practices), on their specific nature as digital computational systems (framing systems), and on their processual nature (framing processes). These views emphasize processuality as a distinctive aspect of these systems, tied to procedural creation and to the performative dimension of their experience, therefore assuming that beyond surface representations we need to focus on their procedural modes of expression and dynamics. Finally, we discuss interdependent and causally linked views (framing perspectives) on their creation, enactment and experience.

2. FRAMING PRACTICES: DIGITAL COMPUTATIONAL SYSTEMS AS AESTHETIC ARTIFACTS

In order to frame the diversity of creative practices that use software as their medium, and are concerned with, or articulated through sound and image, Golan Levin proposes to consider the *principles* that motivate the creation of audiovisual software art. They comprise sound visualization and notation, the transmutability of digital data, interactive performativity and generative autonomy. They correspond to the use of sound or music "to generate aesthetic or analytic visualizations", to works that "map 'real-world' data signals to graphics and sound", or works that "use human performances to govern the synthesis of animation and music", and also to "generative artworks [that] produce animations and/or sound autonomously – from their own intrinsic rule-sets" (Levin 2010, 271-7).

The premise that any information (once digitized) can be algorithmically sonified or visualized, as expressed by the transmutability of digital data, can ultimately be considered as tied to all visualization and sonification practices. Interactive performativity involves user and system in an interactive feedback-loop, while in turn, generative autonomy implies rules as "recipes for autonomous processes" (Galanter 2006) that potentially lead to unforeseeable results, which are not completely predictable neither by artist or user (Boden and Edmonds 2009, 24).

These principles correspond to different ways of exploring the mapping of a given input data or source information into visual and auditory form (tied to visualization and sonification practices linked to transmutability), and to the possibility of devising dynamic audiovisual behaviors and responses to interaction (expressed through generative autonomy and interactive performativity).

As such, they address creative possibilities of a medium where "data and processes are the major site of authoring" (Wardrip-Fruin 2006, 381).[1] The notion of transmutability (including visualization and sonification) therefore puts an emphasis on data as information or content, its mode of representation and perception, and on the mediating transformational process. In turn, generative autonomy and interactivity accent processes, as observable activities performed by the work, defining its surface and supporting interaction.

As Wardrip-Fruin states, "authoring new processes" is a significant means of expression for authors, as a creative opportunity for "defining new computational behaviors" (2012, 7). This view highlights the procedures or operations performed by the work, suggesting that sound and image acquire meaning only as the products of processes, performed with or without the participation of the user. Therefore, the subject matter of these works is not merely tied to surface (audio, visual) manifestations, but by exploring the possibilities of software they propose dynamic, and potentially unique, audiovisual configurations; however, not as an end in itself but as the result and expression of processes. Our attention turns towards the dynamic processes of which the audiovisual surface is a consequence and expression.

The relevance of these principles – understood and used artistically as aesthetic concepts and methods – is that they draw attention to both the digital computation-

1 While data are the "non-process" element of a work, processes are the "procedures or operation carried out by the work", such as those that "respond to interaction, arrange data, and so on", that can be "selected from a set of available options in an authoring system" or "newly-created for the work" (Wardrip-Fruin 2006, 10).

al specificity of these systems and to their diversified nature as aesthetic artifacts. They express what they share, as self-referential works that are speculative and prospective in exploring the possibilities of software as their medium, and also, how they diverge in the subjective discourses and intents they entail as aesthetic artifacts.

3. FRAMING SYSTEMS: AESTHETIC ARTIFACTS AS DIGITAL COMPUTATIONAL SYSTEMS

By framing creative practices and aesthetic artifacts, while emphasizing data and processes as their significant themes, the mentioned principles call for a deeper understanding of the role of digital computation. This refers to work that uses computers for computation and not only as storage and transmission media. It requires computation not only for its authoring but also during its experience, and "in a manner that defines the work". Rather than "fixed" (or containing nothing within their process definitions that leads to variation), this is "reconfigurable and process-oriented work; it "explicitly includes processes of digital computation in its definition" in order to be itself (Wardrip-Fruin 2006, 19).[2]

Consequently, and as Manovich asserts, "instead of fixed documents whose contents and meaning could be fully determined by examining their structure... we now interact with dynamic 'software performances'"; being that *performance* refers to the fact that "what we are experiencing is constructed by software in real time... as the dynamic outputs of a real-time computation" (2008, 15). What we experience, even as static displays, are the results of ongoing computations, which give us not objects but instances or occasions for experience.

According to the author, what better characterizes these works are the "software operations" that shape them and structure their experience, given that "encoded in algorithms... operations exist independently from the media data to which they can be applied" (Manovich 2001, 121).[3] So these artifacts may produce (audio, visual) artifacts, but are also aesthetic artifacts in themselves, as works that occur while running.[4]

As programmed works they are designed to run – running is their "*raison d'être*"– and one can think of each occurrence of the work as a unique performance (Bootz 2005). This performance may vary in each occurrence according to "internally-defined procedures" that allow the

2 This is works that is "explicitly designed for its surfaces to be experienced in a context employing digital computation" performed by any computational device (Wardrip-Fruin 2006, 19).

3 According to this idea, Manovich questions the limits of the terms 'digital' and 'media' to define what is specific about computational works. The author avoids the term 'digital' emphasizing computation, which defines the 'new' logic behind media, and questions the limitations of the term medium to encompass this logic (cf. Manovich 2001; 2008). Cramer similarly proposes to focus on 'software' rather than 'media', since computers are not just 'media' but "are capable of writing and reading, interpreting and composing messages within the limitations of the rule sets inscribed into them" (Cramer 2002). In accordance with this, rather than using the term media, we consider artifact, work or system (or even work-as-system), whose nature is digital but whose specificity is computational, as suggested by Wardrip-Fruin (2006, 9).

4 As suggested by Dorin *et al.*, their "outcomes may be artefacts (visual, sonic, musical, literary, sculptural, etc.), including static or time-based forms", however these systems, as process creations, are also aesthetic artifacts in themselves (Dorin, *et al.* 2012, 244-7).

work to respond, recombine its elements and reconfigure (Wardrip-Fruin 2006, 2). The focus shifts from the outcomes of processes to the process elements of the work, or the ways in which they operate.

For better understanding this idea it is useful to consider the "forms and roles" of computation that distinguish the ways in which these works operate, according to their computational variability, interaction and source of interaction (Wardrip-Fruin 2006). These are computationally variable works in which "processes are defined in a manner that varies the work's behavior (randomly or otherwise)", that is, either "without input from outside the work's material", with input from external data or processes, or with human input; the latter being specifically "from humans aware of the work", as audience interactive (2006, 397-400). Naturally, these factors of variation (intrinsic rules, or external data or process) may either be exclusive or combined within the work.

These aspects are tied to the principles previously mentioned that stress how these factors, pertaining to variability, become a significant theme or feature of the work: either as its potential autonomy, or being driven by (and exploring) external data, namely human input or performances. This point of view is then conforming to the dynamic nature of works *driven by processes as dynamic systems.*

4. FRAMING PROCESSES: FROM POSSIBILITIES TO AESTHETIC QUALITIES

This framing of systems goes beyond their surface by stressing dynamic behavior as their distinctive quality. It also resumes the principles that are in fact Levin's rephrasing of the main "aesthetic possibilities" inherent to the digital computational medium, namely: interactivity, processuality (tied to generativity) and transmediality (tied to transmutability) (Levin 2003; 2007).[5] These terms again highlight digital data's mutably or "susceptibility to transformation", to be mapped into any tangible (visual or auditory) form (Whitelaw 2008), emphasizing the translation processes performed on non-process elements of the work. Interactivity and processuality again bring to the fore dynamic processes that define the surface and support interaction. In this sense, what they stress is not only a "unique aspect of software as a medium", the fact that "it enables response", but also other

5 In his words, they stress the self-referential nature of computational works that address as their subject matter the 'structures', 'materials' and 'processes' by which they are created, namely: interactivity (the character of the feedback loop established with a user; creative flow, play, cybernetic feedback); processuality (the character of algorithmic processes; generativity); transmediality (the way the senses are addressed in simultaneity; tangibility, audiovisuality, environment) (Levin 2003; 2007).

"fundamental expressions of software" that may include "dynamic form, gesture, behavior, simulation, self-organization, and adaptation" (Reas 2003, 175).

4.1. PROCESS AND PERFORMANCE

The terms process and processuality are not without ambiguity, since they evoke the algorithmic structuring of processes (defined within the work and carried out automatically by digital computation), as well as the idea of the work as a process, or an activity performed in time as a unique performance. According to Levin (2007), processuality is a concept that connects concerns with "building machines that develop processes" and "conceptual descriptions of processes"; an artistic application to processes, their design (as a logical score, a conceptual notation) and execution (Cramer 2002). Processuality then relates to code "as something 'generative'; that is always in progress, and on execution produces unpredictable and contradictory outcomes... in a continuous state of 'becoming'" (Cox, *et al.* 2001, 167).

According to Jaschko (2010) processuality highlights what rule-based processes may generate as forms and behaviors, as processes in "development, flux and change"; however, as both generative and interactive artworks, since "live processes... generate unique configurations and dynamics" performed either by system or by system and user. This view of processes refers to a time-based evolution of sequences of events as results of continuous computations. The notion of process then conflates with that of performance which designates the "quality of a technological artifact in operation" (an execution) and the "live dimension" of its presentation. As Broeckmann (2005) argues, processuality and performativity are essential "aesthetic qualities" of electronic and digital artworks, whose aesthetic experience "hinges, to a large extent, on non-visual aspects" or "machinic qualities" manifested at the level of "movements, of processes, of dynamics, of change". This is another way of emphasizing processes (and performance), as a distinctive expression of these systems, beyond their surface modes of expression.

A more strict view of processes defines them as "the mechanisms of change" that occur within a system, as Dorin et al. establish when considering generative systems. As the authors assert, processes may or may not

be directly apparent to the viewer of a work, since they involve "hierarchical relationships where a global or macroscopic process is composed of many micro processes" (Dorin, *et al.* 2012, 245). Therefore, not all processes are immediately perceptible as observable activities, but more importantly, "not all processes contribute equally to the experience and meaning of digital works", as Wardrip-Fruin asserts (2006, 81). For this reason, he uses the concept of "expressive processing" to "talk about what processes express in their design", which may not be visible to audiences but is central to understanding computational media processes, in their "potential numerousness, repetition and complexity" (Wardrip-Fruin 2012, 7-9).

The concept of "expressive processes" also critically questions what processes operate significantly "as part of the work's expression", questioning the value of considering their "intensity",[6] for relevance is not in process intensity as such, but rather in the intensity of expressive processes; or those that clearly contribute for the work to be itself and more evidently define its meaning and experience (Wardrip-Fruin 2006, 80-1). In addition to this, the author suggests that processes that are designed specifically for the work are easier to identify as contributing to the work's expression (whether by algorithmically generating images or sounds, governing the behavior of the surface, or supporting interaction).

However, a deeper understanding of processes entails distinguishing "implemented processes", as concrete realizations of "abstract processes", which support an "operational logics", i.e. embody an appropriate behavior of that system towards a particular end (Wardrip-Fruin 2006, 214). Furthermore, it entails considering the interplay between the activities "carried out by process defined within the work itself", from those performed by its audience as interactions (139), both seen as agents determining the work's outcomes. This implies that *agency*, as an ability to take action leading to meaningful results – much in the sense described by Murray as "exerting power over enticing and plastic materials" (1997, 153) – can be attributed to both system and user (through the system's reactive agency).

From the perspective of audience interaction this emphasis on expressive processes supports the idea that action and processes leading to observable results, rather than the outcomes of processes – "or actions and process-

6 *Process intensity* is the degree to which a program emphasizes processes instead of data. When a work of digital literature emphasizes the presentation of pre-created words, images, and sounds, those are all data. When it emphasizes algorithms and calculations, those are processes (Crawford, 1987 qtd. in Wardrip-Fruin 2006, 65).

es, as opposed to (re)presentations" – are the core of the aesthetic experience of interactive works (Kwastek 2013).

4.2. PROCESSES AND MODES OF EXPRESSION

These different views emphasize processuality and performativity as fundamental qualities, and concepts, to understanding digital computational systems as aesthetic artifacts. As Jaschko underlines, beyond the "regime of the display" or "visual appearance of a work" the essential aesthetic dimension of processual artworks is that of performativity, which is relative to the 'acts' from which form and meaning arise (Jaschko 2010, 134). These aesthetic qualities are tied to both their generative and interactive potential, and, at the same time, highlight the double status of these works as artifacts and as ephemeral moments for experience.

In this manner, these views underline procedurality as the "principal value" of the computer in relation to other media, as its "defining ability" to execute rules that model the way things behave (Murray 1997, 71). Therefore, understanding these systems as aesthetic artifacts entails moving beyond a "rhetoric of the surface" (Bootz 2005) towards an aesthetic level that is tied to their "procedural rhetoric" or "the practice of using processes expressively" (Bogost 2008, 122–24). This means focusing not only their surface representations or modes of expression, but also on their procedural modes of expression, tied to their behavior.[7] The focus moves beyond the surface towards the dynamics of these systems, or their variable behavior, in each occurrence and in response to interaction. As Simon Penny (2008) asserts, we are experiencing systems that "exhibit dynamic real time behavior, or responsiveness to their environment", thus demanding a new aesthetic category: "aesthetics of behavior".

5. FRAMING PERSPECTIVES: SYSTEMS AS AESTHETIC ARTIFACTS

In other words, these works' content "is their behavior" and not merely the output that streams out, as argued by Hunicke, LeBlanc and Zubek (2004). Supporting this view, is the framework proposed by the authors as a formal approach to understanding computational systems "where the interaction between coded subsystems creates complex, dynamic (and often unpredictable) behavior". These are "designed artifacts that build behavior" via interac-

7 In line with these views, procedurality becomes relevant as a "conceptual grounding and aesthetic focus in artistic creation and appreciation, as an aesthetic pleasure in itself", as suggested by (Carvalhais 2010), and for which he proposes a new "analytical model".

tions, and that can be seen in terms of the "causally linked" perspectives of *Mechanics*, *Dynamics*, *Aesthetics*.[8] From a bottom-up (MDA) perspective, "the mechanics give rise to dynamic system behavior, which in turn leads to particular aesthetic experiences", while from the top-down (ADM) user's perspective, "aesthetics set the tone, which is born out in observable dynamics and eventually, operable mechanics" (Hunicke, *et al.* 2004, 2).

The relevance of this framework is that it makes evident the *interdependency* between these "views, or lens" over systems – separate but inseparable – and at the same time supports an ADM top-down approach. In accordance with this idea, Bogost defends, rather than a "bottom-up, code literacy" approach, we can assume a top-down approach that involves "learning to read processes", namely by interacting with a procedural system "with an eye toward identifying and interpreting the rules that drive that system", its *operational logic*, its modes of operation and action (qtd. in Wardrip-Fruin 2006, 48). Similarly, Wardrip-Fruin argues that our "fundamental challenge is to begin to understand dynamic media systems", focusing "on what code is used to express and construct: the operations of systems". The concept of *operational logics* addresses this idea (by inference and deduction of modes of operation). The author adds that this approach, rather than replace, can expand audience-focused understandings, while "moving beyond frameworks developed for fixed media" (2006, 7).[9]

Complementing this view, Dorin *et al.* discuss existing frameworks focused on processes, asserting that they are often more focused on "medium through which processes are enacted" or "on the means by which the form is achieved" than on the processes that create them. The authors argue the need for a "broadly applicable framework" suited to the description and analysis of "dynamic processes", that can also be "intuitive and flexible" (Dorin, *et al.* 2012, 239).[10] To this end, they favor an "analytical descriptive rather than critical framework" that does not privilege technology. Importantly, they also acknowledge the need to complement this view, not leaving silent the artistic motivations behind these works.

These considerations support the strategy outlined in this paper, which aims at articulating distinct, but also (and more importantly) *interdependent* perspectives on digital computational systems as aesthetic artifacts; per-

8 Mechanics refers to "the rules and concepts that formally specify the [work]-as-system", i.e., its components "at the level of data representation and algorithms". Dynamics describes the "run-time behavior of the [work]-as-system". When considering interaction, it pertains to the "run-time behavior of the mechanics acting on player inputs and each others' outputs over time". Aesthetics designates the "desirable emotional responses evoked by the game dynamics", when confronting or interacting with the work (Hunicke, *et al.* 2004, 2).

9 To this end the author proposes a model suited to consider the operations of digital systems according to the interplay between their constituent elements: data, processes, surface, interaction, author, and audience (Wardrip-Fruin 2006, 9).

10 The authors propose a descriptive framework for generative art composed of four primary elements: entities; processes; environmental interactions; and sensory outcomes (Dorin, *et al.* 2012, 239).

spectives suited to consider both their "poiesis (construction)" and "aisthesis (perception)" (Cramer 2002), while probing into their enacted processes.

The principles, models and frameworks discussed in this paper, in their complementarity, provide a way to actually consider digital *computational* systems, not only as systems but also as aesthetic artifacts. This implies articulating separate but interdependent views, considering: their *conceptual dimension* (regarding their motivations, principles or themes, or what they address as subject matter, as suggested by Levin); to address these aspects as they are computationally implemented (as their *mechanics*, data and processes); and to address the elements of their *experience* – concerning not only their *surface* but also their *dynamics*, or the variable behavior tied to their processual and performative qualities. By articulating such views, we can develop instruments for the analysis and critical understanding of these systems, while tackling deeper on the questions that their conceptualization, actualization and experience raise.

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